Year 2 Progress Report for NASA AISR Grant NNG04GP83G: A Numerical Simulation Tool for Planetary Subsurface Radar

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This document reports the progress of the AISR funded research on development of a simulation tool for the complete orbital planetary ground penetrating radar (GPR) problem. The primary personnel who have been supported by this project are the PI, Prof. Steven Cummer of Duke University, and PhD student Yanbin Xu of Duke University.

The research effort in Year 2 focused primarily on code validation and on demonstrating its value in a real scientific application, namely the quantitative interpretation of data from the MARSIS instrument on Mars Express. This effort resulted in one journal publication and one major conference presentation in Year 2. This is described in more detail below. Our Year 3 effort will focus primarily on finalizing a public version of the code.

Summary of Proposed Research

The primary goal of the proposed research is to develop and deliver a versatile and general simulation tool for the complete planetary ground penetrating radar (GPR) problem. GPR is a relatively mature technology for a variety of planetary subsurface remote sensing applications. Correct interpretation of the planetary GPR data is hence the key to studying the target ground parameters of the unknown planetary bodies. As the investigators know, there are currently no simulation tools available in the planetary community that can include essentially all of the important orbital GPR effects, such as the 2D subsurface features and the ionosphere, and there is a compelling need for meaningful quantitative simulation of the planetary GPR problem, which can help bound the data interpretation and instrument design.

We proposed to develop a versatile computer code for the numerical simulation of the planetary GPR problem from source to scattering to reception. The model will be 2.5D, with 3D fields and the capability for treating 2D subsurface and surface inhomogeneities. The code will be designed to be as general as possible to handle arbitrary planetary ionospheres, arbitrary surface roughness, and arbitrary subsurface electrical parameters and structure. Our approach of basing the simulation on time domain methods, in which the entire computational volume is discretized, handles this generality almost automatically. The computational volume will be split into two pieces, one treating the near surface and subsurface fields and the other treating the ionospheric propagation. By accounting for essentially all of the important GPR effects that can be difficult to compute analytically, the model enables accurate numerical experimentation with realistic instrumental and environmental parameters.

<u>Year 2 Research Accomplishments</u>

In Year 2 we built on the successful Year 1 effort in code development to apply the Matlab-platform code to a data analysis and interpretation problem along the lines initially proposed. Specifically, with collaborator William Farrell of NASA/GSFC, we applied this code to bound the quantitative interpretation of specific measurements made by the MARSIS GPR instrument on Mars express. MARSIS observed some unusual subsurface echos from the south polar cap of Mars in which the subsurface return was stronger than the surface return. Figure 1 shows an example of processed MARSIS data from one of these regions.

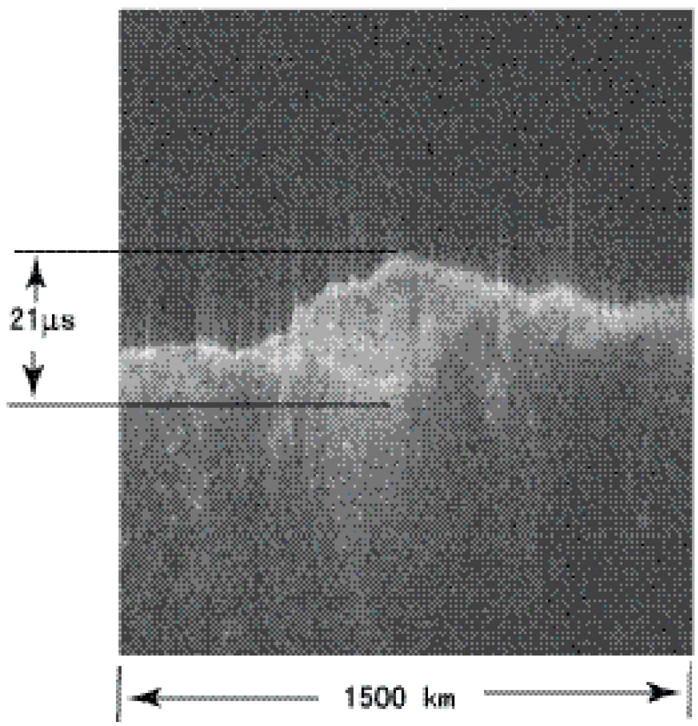

Figure 1: MARSIS data showing surface reflection (the top bright feature) and subsurface reflection (the lower bright feature) in which the subsurface reflection is brighter than that from the surface.

Given how little is known about the Martian subsurface, there are too many free parameters to give a unique solution to this problem. Consequently a model is needed in order to constrain the parameters that could be consistent with the measurements. Figure 2 shows a simulation run that is able to reproduce the measurements with reasonable precision. The surface and subsurface parameters that went into this simulation, shown in the left panel, are thus consistent with the data, although they are not the only possible set.

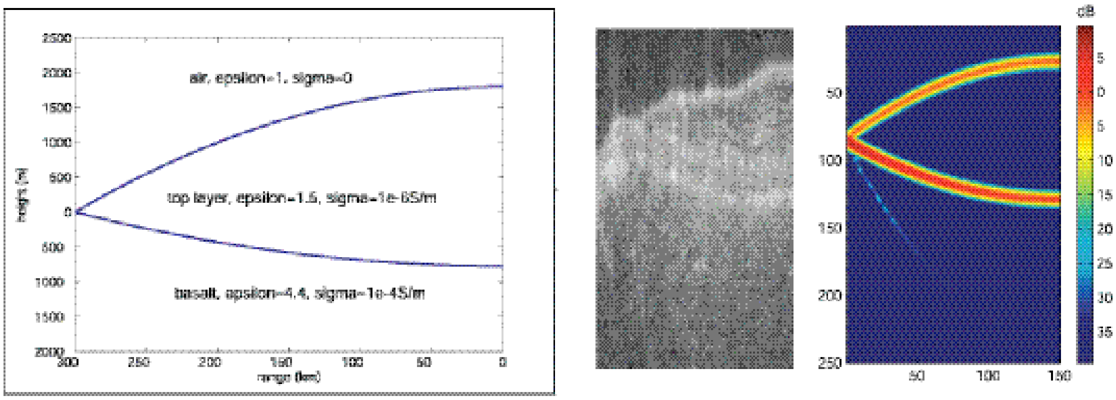

Figure 2: Closeup view of the MARSIS data along with results from a simulation that reproduce the measurements to good precision. The surface and subsurface electrical parameters in the left panel are thus consistent with the measurements.

We have run a series of simulations with different parameters, including variable roughness of both the upper and lower interfaces in order to determine the set of physically reasonable parameters that are consistent with the data. A manuscript based on these results is currently in preparation.

In essence, this effort has validated the original motivation for the research effort. Ambiguities are substantial in a problem like planetary GPR, and a versatile, full-wave model is needed as a data analysis tool to explore all the possible scenarios that could be consistent with the measurements.

<u>Publications and Presentations in Year 2</u>

Xu, Y., S. A. Cummer, and W. M. Farrell (2006), Application of an orbital radar sounder model to detecting Martian polar subsurface features, J. Geophys. Res., 111, E06S17, doi:10.1029/2005JE002547.

Xu, Y., S. A. Cummer, and W. M. Farrell, Application of an orbital GPR model to detecting ground ice and deep liquid water under the Mars polar cap, American Geophysical Union Fall Meeting, December 5-9, 2005, San Francisco, CA.

<u>Tasks to be carried out in Year 3</u>

Year 1 produced a working version of the codes based on the Matlab platform. Year 2 applied these codes to solve a real research problem and demonstrate the capabilities and value of these codes.

The research effort in Year 3 will be to complete a cross-platform version of the codes suitable for wide distribution (although the Matlab codes are suitable for use by those familiar with the platform and is probably easier to use), and continue to solicit feedback from the community regarding the features and usability of the code. We also plan to continue to apply the code to research problems in our ongoing collaboration with members of the MARSIS team.